FINAL REPORT

OCTOBER 1967

AUTOMATIC IMAGE REGISTRATION EXPERIMENTAL PROGRAM

STAT

FINAL REPORT

OCTOBER 1967

AUTOMATIC IMAGE REGISTRATION EXPERIMENTAL PROGRAM

STAT

STAT

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

TABLE OF CONTENTS

1. Introduction

2. Technical Discussion

    2.1 EROS Preparation

    2.2 Experimental Program Description

        2.2.1 Photo Materials Preparation

        2.2.2 System Reference Data

        2.2.3 Precision and "Zero Parallax" Determination

        2.2.4 Clearance Error Measurements

        2.2.5 Experimental Results

    2.3 Image Point Selections

    2.4 Data Evaluation

        2.4.1 Measuring Mark vs. Raster Relationship

        2.4.2 Raster Size Determination

        2.4.3 Measuring Mark Motion Calibration

        2.4.5 Stereo Parallax Errors

3. Conclusions and Recommendations

4. Appendix A - Technical Report - EROS

   Appendix B - Film Diapositives - Scale 1:10,000

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

1.0 INTRODUCTION

All present automatic image registration systems are dependent for operation upon the scanning of appreciable areas of the involved stereo images. Additionally, current systems are limited to zero and first-order transformation capabilities which correspond to translational and slope-correctional facilities. Consequently, since usual terrain forms are not planar in nature, the registration system achieves the best average registration over the scan area. This leads naturally to the existence of registrational error at the central point of the scanning pattern which is the point of mensuration in all systems. Little if any test data has been available with which to evaluate the magnitude of averaging errors when measuring with an automatic image registration system. The completion of EROS which is described in the report attached as Appendix A, has presented the first opportunity to derive test data which allows a useful evaluation of this problem. This report describes the experimental program conducted for the extraction of data, the analysis of that data, and the conclusions and consequent recommendations derived therefrom.

2.0 TECHNICAL DISCUSSION

This program has been executed in three parts:

- EROS preparation
- Experimentation and data recording
- Data evaluation

The essential components of these parts are discussed in the following paragraphs.

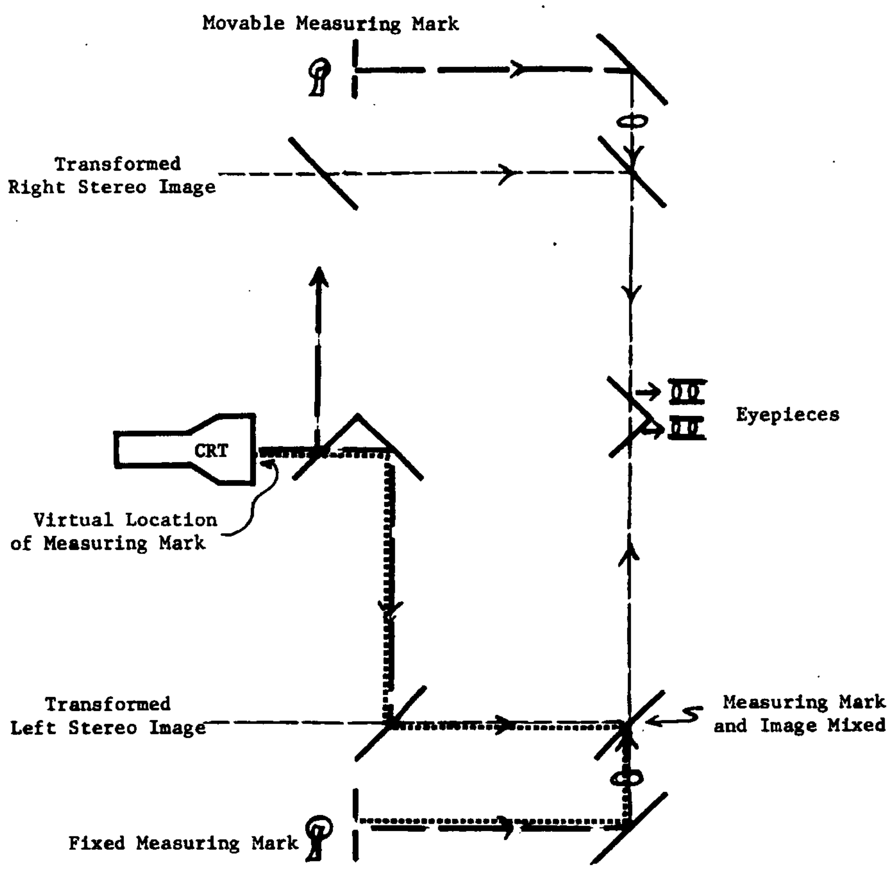
2.1 EROS Preparation

EROS in its original configuration was not supplied with any form of measuring marks or attendant mensuration capability. Consequently, it was necessary to incorporate these means into the optical system before tests were possible.

Realizing that EROS registers images in two channels with respect to a single scanning raster, that the optical axes in EROS cannot be expected to remain stationary and that it is impractical to introduce mensuration means into the EROS transport system, it was decided to introduce the required measuring marks at the real image planes within the eyepieces. Figure 2.1 illustrates the optical-mechanical realization of this scheme. It should be noted with respect to Figure 2.1 that the left measuring mark is stationary and the right is moveable over a small motion range. The left mark then, has a fixed relationship to the scanning pattern if one neglects accidental shifts of the pattern owing to stray magnetics. The range of motion of the right mark need only be small owing to the fact that any gross parallax between images is automatically eliminated by the registration system. The position of the right mark is signified by readings (0.0001 inch least reading) on micrometer barrels; one each for p_x and p_y. The marks themselves are 0.0010 inch diameter apertures illuminated from the rear by lamp sources. To allow the operator to clear parallaxes, drive rods extend from the micrometer screws forward to the front of the instrument. Owing to the fact that EROS's zoom optics slightly change the location in space of the final real image when the zoom is changed, the additional required features were focus adjustment mechanisms. These features merely allow the maintenance of coplanarity of the photo images and the measuring marks; this making the measuring marks sharp under all zoom conditions.

2.2 Experimental Program Description

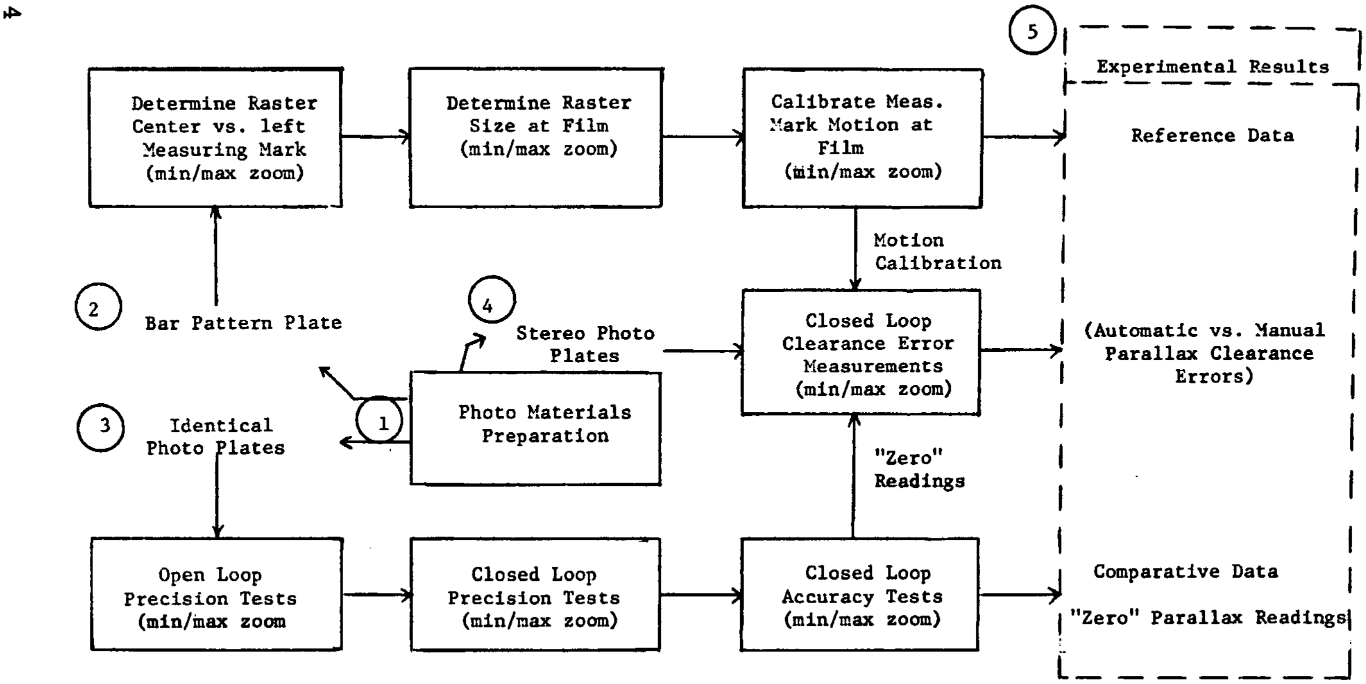
The experimental program conducted was comprised of several preparation and data gathering operations. Figure 2.2 illustrates the composition of the program.



3

Figure 2.1 - Measuring Mark Insertion Diagram

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8



NOTE: Stereo Plate Characteristics:

Camera [redacted]
Focal Length - 6 inches
Altitudes - 5, 10, and 15 thousand feet
Attitude - vertical
B/H Ratio - 0.6

Figure 2.2 - Experimental Program

Referring to Figure 2.2, it is seen that the experimental program is divided into five general categories of work, each of which is composed of one or more individual elements. The first category of work relates to the preparation of photographic material necessary to the completion of the experimental program. The second category of work relates to the determination of certain EROS parameters which are crucial to the experimental program. The third category of work relates to the establishment of precision levels attainable for parallax clearances under differing circumstances and to the parallax readings that correspond to zero parallax between the test images. The fourth category relates to the determination of parallax clearance errors associated with the automatic registration of stereo images of specific types of object-space, terrain and feature shapes. Then in category five, the numerical results of categories two, three, and four work must be brought together in order to derive understandable results from the experimental program. More detailed discussions of the categories and elements therein are as follows.

2.2.1 Photo Materials Preparation

There are two reasons for photo materials preparation. First, it is necessary to provide the stereo images of certain terrain configurations containing likely causes of correlator error so that the effect of these causes may be evaluated. Second, the photographic materials must be so constituted as to provide control for the experimental work so that instrument-induced errors not associated directly with correlation may be eliminated from consideration. Three types of photographic imagery are necessary to achieve these dual ends.

The first photographic image produced was that of an equal bar and space rectangular pattern. The widths of the bars and spaces are 1/32". The spacing of the bars and spaces has been used to calibrate the relationship between measuring mark motion in the input image and difference between micrometer readings. Additionally, this pattern has been used to ascertain the relationship between the stationary measuring marks and the scanning pattern. To do this the corner of the bar pattern is brought to the stationary measuring mark. Subsequently, the video information produced by the scanning system was displayed in a coincident scan pattern on an oscilloscope. The resulting display was photographically recorded and the image measured to determine the location of the corner of the bar pattern within the framework of the scanning pattern. The objective of this measurement was to determine the proximity of the measuring mark to the center of the scanning pattern. [redacted] This location is of importance in that when registering the stereo image of curved terrain, the maximum parallax error occurs at the center of the scanning pattern when the correlator transformation system has only first order capability.

The second set of photographic materials produced were stereo images exposed over the same terrain, but from three different altitudes; five, ten,
STAT and fifteen thousand feet using a [redacted] six-inch focal length RC5A camera (See Appendix B for duplicate samples of film diapositives forming a stereopair taken at five thousand feet altitude, scale 1:10,000.) The reason for using three photographic scales is that one would like to ascertain the significance of registration errors over the same object points under differing photographic scale conditions as well as under differing zoom conditions.

In order to provide a reference for parallax readings made on stereo photographs, it was necessary to prepare a third set of photographic materials. These photographs are identical copies of the left-hand stereo images. They were printed however, so that the area of the image to be used for the stereo test is at the left side of the diapositive plate and in approximate coincidence with the location of that same area on the right-hand member of the stereo pair. These materials were produced in this manner for two reasons. First, if we measure numerous points in identical photographic plates, then we should achieve the same parallax reading for all points. This parallax reading then is the reference "zero parallax" reading. If, subsequently, we register two stereo images and do not get the same parallax reading when the measuring mark is put on the terrain, then the difference is the error in the automatic registration process.

The reason for producing the above described identical images on the left-hand side of the diapositive plate is that such a precaution materially reduces any possible parallax error which might be found owing to the non-linearity of transport motion in EROS. In essence, we want to determine the zero parallax reading with the transport plate carriers in the same relative positions as will be the case when we test using stereo inputs. It should be noted in this context that the selection of points to be tested for stereo registration errors were selected with consideration for the equality of total parallax between points. Again, this was done to limit in so far as possible any changes in relative position of the two transport photo carriers.

2.2.2 System Reference Data

As mentioned previously in the context of photo materials preparation, the category of work relating to system reference data is included in the experimental plan in order to relate EROS characteristics to the tests being

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

performed. In essence, we must know the relationship between the stationary (left) measuring mark and the scanning raster. Similarly if we want to know the relationship of the scanning raster to the measuring mark, we also need to know the area represented in the film by the scanning raster during operation under various zoom conditions. This is necessary in order that we may evaluate any parallax errors in relationship to the height anomalies existing within the scanned area. Additionally, we must define the relationship between the differences in micrometer readings and the motion of the measuring mark in the plane of the input photographs. Through this calibration we can convert micrometer readings into microns in the film which is necessary in order to derive the height errors in the terrain corresponding to these parallax errors.

Each of the above factors has been investigated at each of the two zoom settings that have been used in the actual image mensuration tasks.

2.2.3 Precision and "Zero Parallax" Determination

As background to any stereo registration tasks, it is necessary to establish the precision levels to which parallax may be cleared under ideal conditions. Also, it is necessary to establish "zero parallax" readings, or in other words, the micrometer position readings at which the two measuring marks are in virtual superposition on the scanning pattern. To accomplish these ends we have resorted to the use of identical photo-images in both channels of EROS. This is the best registration condition that one could expect to achieve in that the images are not dissimilar in geometry as is the case with stereo imagery.

The first test was performed in the following manner. With EROS correlating normally the transport was moved until one of the selected image points was coincident with the measuring marks. At this time the EROS correlator was disconnected and the operator performed ten consecutive registrations at the point involved. The precision of these settings is the best that the operator could be expected to achieve in that the disconnection of the correlation system has removed all optical and mechanical motion errors from the system. This operation was repeated at each of the selected points.

One would expect that the next lower level of precision would be achieved when the operator takes multiple readings at each point with the correlator and servo loops operating. Thus, this was our second set of readings.

The third level of precision to be expected and the condition encountered which defines the "zero parallax" readings is that wherein the operator takes readings at each consecutive point and circulates through the points to achieve the number of repetitions required. This procedure insures that such transport errors as may be expected to degrade stereo measurements are brought to view and considered in the analysis. The average parallax readings at each point resulting from this operation are the reference against which we gauge stereo parallax readings. The difference between the two averages at each point is the averaging error caused in the automatic registration by parallax anomalies within the scan area.

2.2.4 Clearance Error Measurements

Two types of measurement data were taken by two different measurement means in the clearance error measurements portion of the experimental program. The primary data taken was that relating to the differences between automatic registration of the images and the manual registration of the images. As previously alluded to, these data were taken by circulating among the selected points with EROS in a closed loop registration condition and at each point having the operator adjust the x-position of the right hand measuring mark until the floating mark in the stereo view was in contact with the point. The operator then recorded the micrometer reading corresponding to the measuring mark position as a consequence of manual registration. This circulatory mode of data recording was continued until ten observations had been made at each point selected in the photographs.

The second type of measurement accomplished was performed on the photographic images using a mirror stereoscope and parallax bar. These measurements were performed to define the amount of parallax introduced by the height anomalies within the scanned area. By taking this data we then had at hand the location of the height anomalies within the scanned area by reference to the photographic image and also the magnitude of those height anomalies. The intent here is to attempt to relate the location and magnitude of height anomalies to the registration error engendered by that height anomaly at the center of scan.

2.2.5 Experimental Results

The final task in the experimental program was to reduce the data taken into a form susceptible to analysis. For instance, this part of the program comprised the reduction of zero parallax readings and standard errors of settings. Additionally, the standard errors of setting were converted into standard errors in "heighting" in the terrain so that their magnitudes became relatable values.

The other task that was performed in this portion of the program was to prepare the photographic materials which illustrate conditions selected and tested.

2.3 Image Point Selections

In keeping with the time and funding restraints of the program, only six points were selected for investigation at the two zoom settings and three scale conditions. Figures 2.3a and 2.3b are five times enlargements of two areas of a 1:10,000 scale photograph upon which are marked the specific points at which observations were taken. It should be noted that at this enlargement, the scanning raster sizes at minimum and maximum zoom were 130mm square and 40mm square, respectively. (See also Appendix B.)

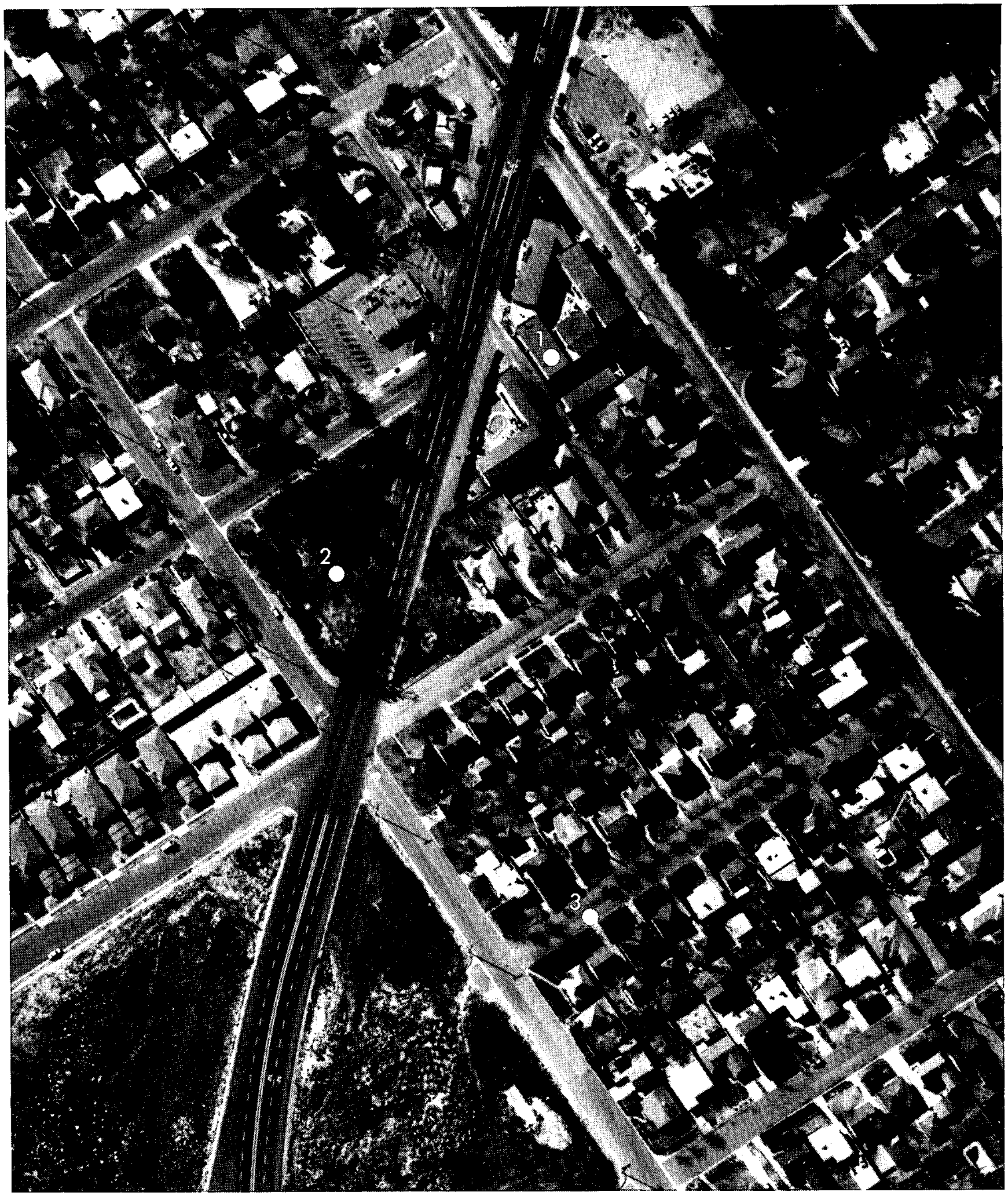


Figure 2.3a - Location of Image Points
(5x enlarged portion of 1:10,000 scale photograph)

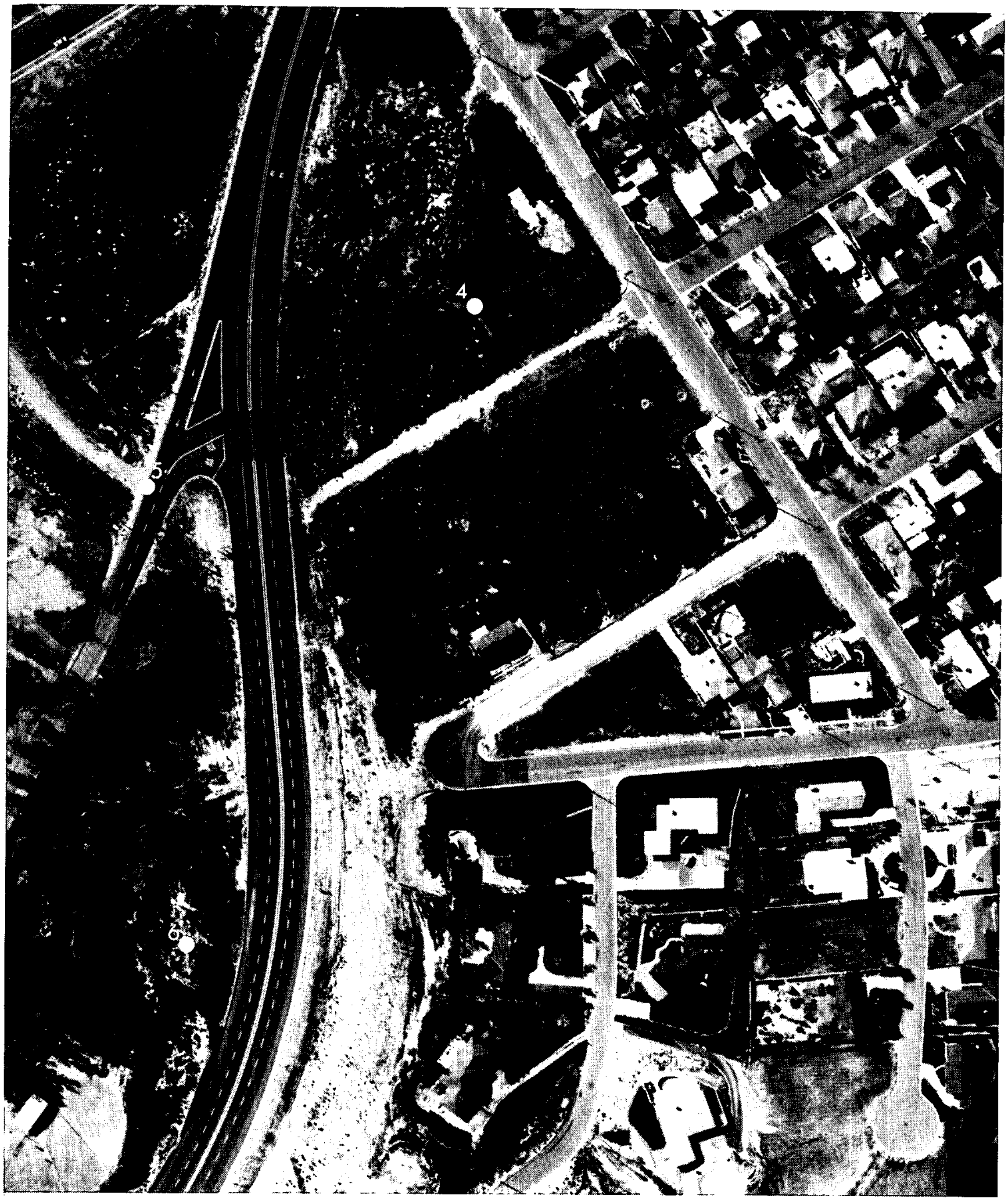


Figure 2.3b - Location of Image Points
(5x enlarged portion of 1:10,000 scale photograph)

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

The points selected are of three different characters. Point one was selected atop an upward projecting building. The error here is between both the top of the building and the scan pattern and between the scan pattern and the ground. Points 2, 3, 5, and 6 were chosen so that height anomalies lifted the scan pattern from the ground while the point of interest was on the ground. Point 4 was chosen on a relatively planar, but sloped portion of terrain. This selection should provide minimum error between correlator and operator settings. Conformance of results to plans for points is discussed in Section 2.4.

2.4 Data Evaluation

2.4.1 Measuring Mark vs. Raster Relationship

As discussed in Section 2.2.1, a square bar pattern was used to evaluate the position and variability of position of the stationary measuring mark with respect to the center of the scan pattern area. Owing to poor video quality in a photographic sense the polaroid test photos are not included herein, but Figure 2.4.1 depicts the character of the photographic results.

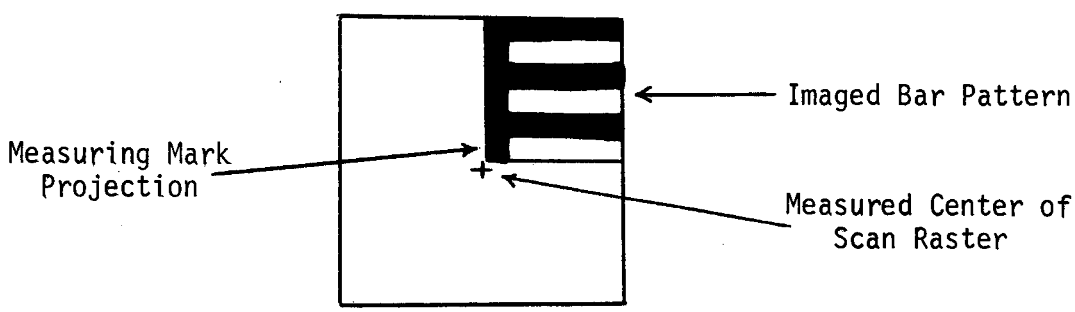


Figure 2.4.1 - Illustration of Measuring Mark Projection Test Images

The measurements of these images showed that for all trials the measuring mark did not depart from the raster center by more than 3% of the raster width. This amount of displacement is insignificant in the tests performed.

2.4.2 Raster Size Determination

As discussed in Section 2.2.1, a double bar pattern was used to determine scan size at the photographic image plane. Figure 2.4.2 illustrates the type of Polaroid photographic image used in this evaluation.

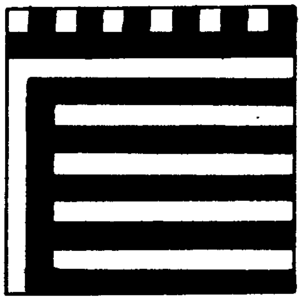


Figure 2.4.2 - Illustration of Raster Size Test Images

The known bar-space pattern in each image having orientation in two directions allowed the evaluation of scan dimensions. It was found that at minimum and maximum zooms respectively, the scan sizes at photo scale were 26mm and 8mm. These sizes define the area scanned around a test point in the photo imagery regardless of photo scale.

2.4.3 Measuring Mark Motion Calibration

Measuring mark motion calibration in the plane of the photo images was accomplished using bar patterns oriented first in x and then in y direction. The right (movable) measuring mark was set visually upon the edge of a bar. A micrometer reading was taken and the measuring mark moved over one bar-pattern cycle to the edge of the next bar. The difference between the micrometer reading at the second bar edge from that at the first related to the actual bar-pattern cycle dimension provided the conversion factor from the micrometers to the photo scale. It was found that the conversion factor between micrometer readings and photo distances is 1.77 inches/inch at minimum zoom and 0.55 inches/inch at maximum zoom.

2.4.4 Parallax Clearance Precision

As discussed in Sections 2.2.3 and 2.2.4 and depicted in Figure 2.2, identical and stereo images were registered under low and high zoom conditions, three system conditions and three photographic scale conditions. In all 2160 parallax clearance observations were accomplished in compiling the statistics needed in the program.

Tables 2.4.1a, b, and c show the results of precision (repeatibility) derived from multiple observations. It will be noted that each table relates to one photographic scale. Within the tables are recorded the standard errors of observations (in microns) for the matrix of conditions established.

With respect to the tabulated data, certain observations appear in order. They are as follows:

- As expected y-parallax clearance is less accurate than x-parallax clearance, since dove prisms are not available in EROS to switch y-parallaxes to the x-direction.
- Precision decreases when changing from the most quiescent mode (open loop) of operation to the more dynamic mode which combines closed loop operation with transport errors.
- Precision increases under the effects of higher system magnification.
- Precision of registration is a function of photo-machine resolution and not a function of photographic scale.

Table 2.4.1a - Standard Errors of Observations
(At photographic scale in microns)

	Scale 1:10,000		Open Loop	Closed Loop	Closed Loop and Transport
Identical Plates	Low Zoom	σ_x	4	7.5	7
		σ_y	9	7	7
	High Zoom	σ_x	2.5	4	5.5
		σ_y	3	4	9
Stereo Plates	Low Zoom	σ_x	6	6	8
		σ_y	7	9	11
	High Zoom	σ_x	2	5	6
		σ_y	4.5	5	6

Table 2.4.1b - Standard Errors of Observations
(At photographic scale in microns)

	Scale 1:20,000		Open Loop	Closed Loop	Closed Loop and Transport
Identical Plates	Low Zoom	σ_x	6	7	8
		σ_y	7.5	9	11
	High Zoom	σ_x	3	5	4
		σ_y	2	5.5	6
Stereo Plates	Low Zoom	σ_x	5	7	6
		σ_y	6	8	9
	High Zoom	σ_x	2	4	5
		σ_y	3.5	4	6

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

Table 2.4.1c - Standard Errors of Observations
(At photographic scale in microns)

	Scale 1:30,000		Open Loop	Closed Loop	Closed Loop and Transport
Identical Plates	Low Zoom	σ_x	5	5	9
		σ_y	5	7	11.5
	High Zoom	σ_x	1.5	3	3
		σ_y	3	3	4
Stereo Plates	Low Zoom	σ_x	4	4	8
		σ_y	6	6	11
	High Zoom	σ_x	2	4	6
		σ_y	3	3.5	8

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

- Precision of registration of the human operator is not significantly dependent upon whether the images are identical or stereo.
- The average x-parallax clearance precision of the operator using EROS (open loop) with stereo photographs is five microns and two microns respectively, for low and high zoom conditions.
- The average x-parallax clearance precision of the operator-machine system with stereo photographs is seven microns and six microns respectively for low and high zoom conditions.
- The average precision changes indicate that vibration, correlator and transport errors add about five microns to the standard error of registration in EROS. Since this addition is nearly the same at both zoom conditions, it is evident that accidental transport errors are larger than correlator errors. Otherwise, there would be a similar difference in precision at the two zooms as for the human operator. This suggests that the right plate dc-servo motor system does not operate with sufficient precision to allow better registration mensuration results. However, since EROS was not designed as a mensuration instrument this lack of precision in the servo loop is not unexpected.

2.4.5 Stereo Parallax Errors

Considering the foregoing, it may be stated that measurements of stereo parallaxes have a precision in the order of seven microns at the input photo scale. This means that at the photo scales used, the elevation determination precision on the ground was:

(1:10,000)

(1:20,000)

(1:30,000)

STAT

These values are computed by the well known approximate scaling equation

$$\Delta h = \frac{H}{b'} \Delta p$$

wherein H is the flying altitude, b' is the stereo base distance at photo scale, Δp is differential x-parallax, and Δh is the corresponding differential height on the ground.

With respect to the difference in parallax values between registrations of identical plates and stereo plates, Table 2.4.2 depicts registration differences in feet-of-height at the ground. These heights were computed by the same approximate equation as described above. It should be noted that the difference in height is that difference between the scan pattern's virtual location with respect to the terrain and the measuring mark as set on the point by the operator.

Referring to Table 2.4.2 and Figures 2.3a and 2.3b, the following observations are made with respect to parallax differences:

- Point 1 is atop one of a group of buildings. However, the scanning pattern at all acales and zooms is much below the top of the building. Especially at lower zoom and smaller scales, the image information on the ground is much stronger than that at the tops of the buildings in the area, thus the scanning pattern closely approaches being on the ground. At high zoom where less area is covered by the scan raster, it is noted that the raster climbs up the building considerably.
- Point 2 is on the ground among trees. Table 2.4.2 figures show that the trees and buildings surrounding the point raise the raster from the ground. Only at smaller scales and low zoom does ground information bring the raster to the ground.
- Point 3 is on the street in a residential area. At this point it is

Table 2.4.2 - Area Correlation Height Errors
(Feet on the ground)

	Point	Photo Scale		
		1:10,000	1:20,000	1:30,000
Low Zoom	1	- 16	- 21	- 30
	2	+ 6	+ 2	+ 1
	3	+ 7	+ 6	+ 10
	4	+ 1	+ 6	+ 13
	5	+ 1	+ 1	0
	6	+ 1	+ 5	+ 6
	Ave/ h	0/8	0/9	0/14
High Zoom	1	- 13	- 12	- 11
	2	+ 6	+ 8	+ 9
	3	+ 8	+ 9	+ 8
	4	- 1	- 5	- 2
	5	+ 2	0	- 4
	6	- 2	0	0
	Ave/ h	0/7	0/7	0/7

seen that the averaging effect of the correlator is quite different from that at point 2. At this point the raster is considerably off the ground at all scales and zooms.

- Point 4 is in a sloped open field. The errors at this point occur as would be expected. At higher zoom and larger scale, the errors become quite small. Only when large areas are covered by the raster does error increase.

- Point 5 is at the edge of a road where hard x-image information is available. As a consequence it will be noted that errors are small under all conditions of averaging.

- Point 6 is in a sand and brush area of high contrast. Here again local image conditions appear to keep error low especially under high zoom conditions where peripheral conditions are excluded.

It is interesting to note in Table 2.4.2 that the average error at the six points under each condition is approximately zero. With respect to the standard error at the six points, the average [redacted], but it is evident that the smaller the area on the ground represented by the scan raster the smaller will be the error. This confirms the philosophy used in automated stereo plotting instruments wherein scanning rasters are made quite small to avoid averaging errors when only first order transformation capability is present in the instrument. The disadvantage of the area reduction approach is that at some point reliability of correlation becomes impaired.

STAT

3.0 CONCLUSIONS AND RECOMMENDATIONS

The above described test program has been sufficient to provide the basis for four conclusions concerning the EROS instrument. These conclusions are as follows:

- The optical system has sufficient resolution to support manual measurements in the micron range.

- The registration precision of the correlator is something better than ±7 microns at photo scale.

- The introduction of measuring marks at the eyepiece is a workable method for a mensuration instrument if the photo stages are supplied with micron accuracy mensuration capability. The summation of plate and micrometer measurements would provide accurate results regardless of the inaccuracies of the transforming optics included between the photo and the eyepiece.

- The correlator itself cannot be used as a means to derive measurements of height of buildings, etc., when only first order transformation capability is present in the system.

On the basis of the results of this study it is recommended that no further testing of this specific nature be accomplished. The capabilities and limitations of instrumentation similar to EROS have been established in sufficient detail for future system engineering purposes.

Appendix A

Electronic Registration Optical Stereoscope

(EROS)

CONTENTS

		Page
1.	System Description	1
	1.1 Optical System	1
	1.2 Scanning System	3
	1.3 Correlation System	4
	1.4 Servo System	5
2.	Performance of EROS Feasibility Model	9
	2.1 Optical System	9
	2.2 Scanning System	10
	2.3 Correlation System	10
	2.4 Viewing Tests	13
3.	Requirements for Future Equipment	21
	3.1 Optical System	21
	3.2 Scanning System	22
	3.3 Correlation System	23
	3.4 Servo System	24
4.	Conclusions	26

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

1. System Description

The EROS equipment was built as a feasibility demonstration model to prove the feasibility of combining electronic automatic registration techniques with a purely optical viewing system. The stereoscope was built as a breadboard with no intention of its being used as an operational instrument. Off-the-shelf components were used as far as possible, and the equipment was designed to accept input transparencies on 9-1/2 x 9-1/2 glass plates, using an air bearing transport system.

1.1 Optical System

The optical system is based on four major components which between them introduce the four first-order geometrical distortions: (1) Zoom Lens; (2) Rotation K-mirror; (3) and (4) Anamorphic lenses. The four first-order distortions can be defined in various ways. The simplest definition is in terms of X and Y components i.e.,

X scale

Y scale

X skew

Y skew

This method is inconvenient when dealing with an optical system, because most optical components operate on a two-dimensional image field. The distortion parameters used in EROS are therefore

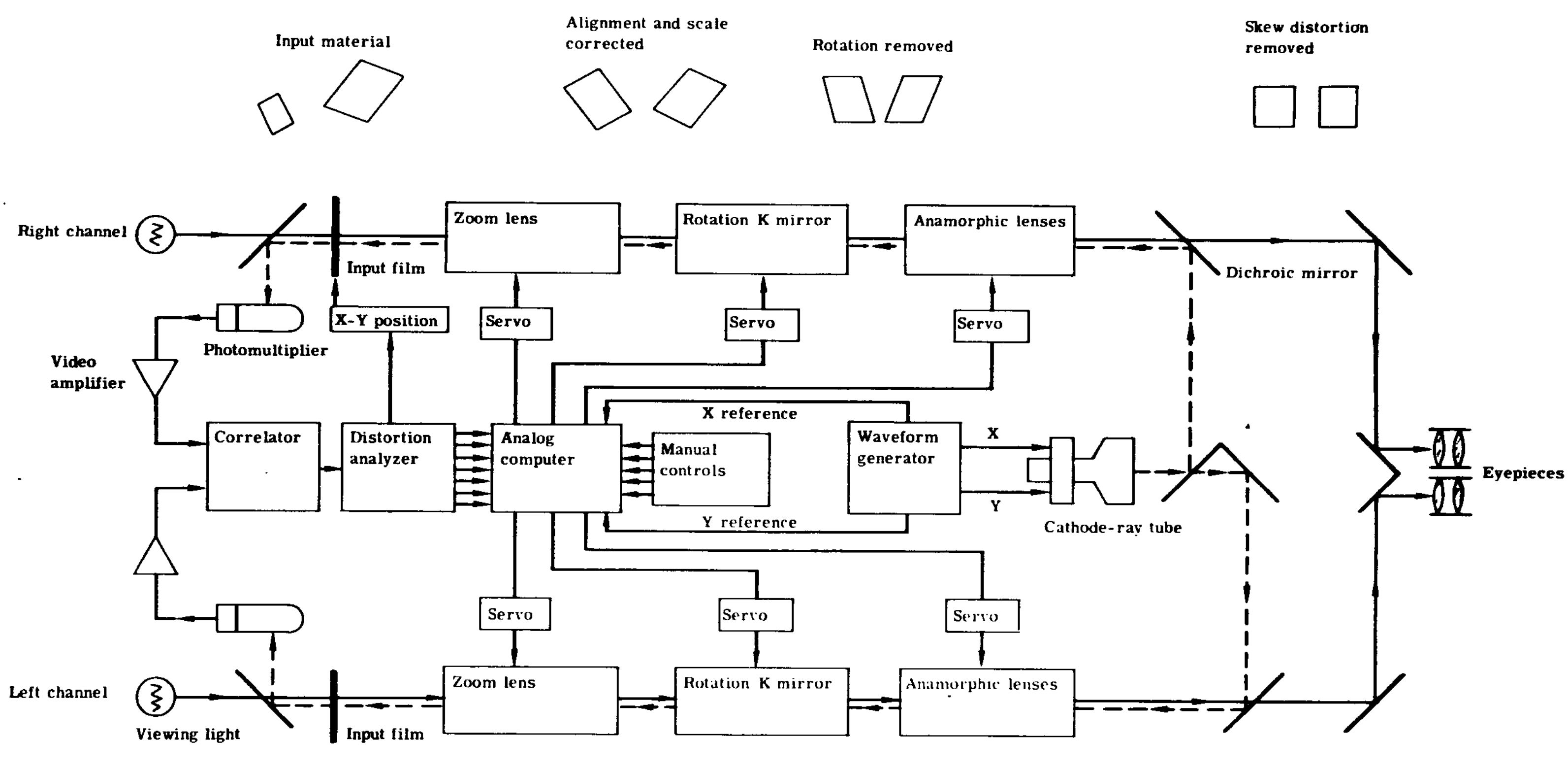
Uniform Magnification	
Rotation	
Anamorphic Magnification	Magnitude
Anamorphic Magnification	Direction

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

Uniform magnification is implemented by two Angenieux 100-400mm f/5.6 Zoom lenses, one in each leg. These lenses were originally designed for use with TV image orthicons and are computed for infinite conjugates. In the EROS equipment it is consequently necessary to combine the zoom lenses with collimating lenses, for which purpose the 480mm f/4.5 Schneider Xenar was selected.

Image rotation is accomplished by means of two K-mirrors, one in each leg. Anamorphic magnification is provided by four anamorphic adapters, two in each leg. These lenses designed for use as Cinema-scope adapters in conjunction with a regular projection lens, and magnify the image by 2x in the horizontal direction and by 1x in the vertical direction. Each anamorphic consists of a positive and a negative cylindrical lens (achromatic doublets or triplets), the spacing between which is extremely critical. These anamorphic adapters normally operate with nearly collimated lights and to use them in the present equipment a collimator and decollimator must be employed. Optical bench tests at the start of the program determined that achromats of about f/7 aperture were adequate for use as collimators, as they possessed significantly lower spherical aberration over the small field angle required than the 480mm Xenar camera lenses. Also, it was determined that the best resolution was obtained with the anamorphic lenses back-to-back.

The complete optical system is shown in Figure 1. The light sources consist of 30 watt 115-volt projection lamps with translucent diffusing screens mounted on the condenser lenses. The lamp brilliance is continuously adjustable by means of an SCR control circuit.



EROS feasibility demonstration model, functional diagram

FIGURE 1

Before entering the zoom lens, the input image is magnified by 2.5x by means of a Schneider Comparon 100mm f/4 enlarging lens, specially computed for this magnification. Simple field lenses are provided at the two image planes in the system.

The eyepieces used are 10x B & L wide field. Interocular adjustment without change of focus is provided by relative movement of both the eyepieces and the 45^0 diagonal mirrors. Provision is made for removing the eyepiece assembly and replacing it with a Polaroid back in order to make a hard copy of the viewed images.

1.2 Scanning System

Scanning the two input transparencies is achieved through an optical duplexing system. The scanning pattern originates on the face of a 5ZP16 CRT and is inserted into the optical system by means of pellicle beam splitters with dichroic coatings. The P16 phosphor peaks at around 4,000Å; the dichroic mirror reflects 90% of the light below 4,500Å and transmits 85% of the light above 5,000Å. The scanning light passes through the optical system in the reverse direction to the viewing light causing the scanning spot to be reimaged on the transparency. The blue scanning light transmitted by the transparency is separated by a further dichroic mirror, collected by a condenser lens and is made incident on the photocathode of a photomultiplier tube which converts the light fluctuations into a video signal. To prevent scattered light from the projection lamp from entering the photocell, the projection light is filtered with a Wratten No.12 minus blue filter and a further No. 47B blue filter is placed in front of the photocell.

1.3 Correlation System

The correlation system employed in EROS is based on that developed for the ARES viewer. A Lissajous crossed diagonal scanning pattern of 64 lines is employed, this giving adequate resolution for image correlation. The line frequency is approximately 3 kH_Z using 30 frames per second with an interlace of 2:1. The scanning waveforms are derived from a 780 kH_Z l-c oscillator. The output of this oscillator is first divided by 2 and then divided by ratios of 63 and 64.

A further division by 2 reduces the square wave frequency to about 3 kH_Z. The triangular scanning waveforms are generated by an integrating circuit. The deflection amplifiers have current feedback by which means the output current waveform applied to the CRT deflection yoke is forced to follow the amplitude of the input voltage.

The resistance of the deflection coils was compensated by introducing a step into the scanning waveform, so that a good triangular current wave was obtained.

The correlators and distortions analyzers followed the 1965 ARES design except that all frequencies were reduced to 1/5 because of the reduction in line frequency from 15 kH_Z to 3 kH_Z. Only two frequency bands were employed, 21·5 - 46·5 kH_Z and 46·5 - 100 kH_Z respectively.

The distortion analyzer gave the normal zero - and first order error signals:

X parallax

Y parallax

X scale

Y scale

X skew

X skew

1.4 Servo System

1.4.1 X and Y Parallax

All image distortions are compensated mechanically or optically in this instrument. X and Y parallax are corrected by means of two DC Globe motors mounted on the air bearing film transport. The servo amplifiers are operated directly from the X and Y parallaz output of the distortion analyzer. The R-C filter time constant at the output of the distortion analyzer must be adjusted to eliminate most of the correlation noise, as this can easily saturate the servo amplifiers, resulting in decreased loop gain.

1.4.2 Zoom Lenses

The uniform magnification error signal is obtained by adding the X scale and Y scale errors. It is then applied in opposite polarity to the servo amplifiers driving the two zoom lenses, so that the difference in magnification is taken out equally on both sides. In addition, to responding to differences in magnification between left and right images, the zoom lenses must also accommodate the manual zoom control. This is achieved by using a position servo with follow-up pots which controls the average position of the two zoom lenses. The manual zoom and automatic differential magnification controls remain completely independent because the average position is unaffected by equal positive and negative changes in the two lenses.

In the manual mode, the differential magnification is controlled from a front panel potentiometer with position feedback derived from the difference between the outputs of two follow-up pots on the zoom lenses.

1.4.3 K-Mirrors

The rotation error is given by the difference between the X-skew and Y-skew errors, and is applied to the K-mirror servo amplifier. The servo motor, a Printed Motors Incorporated Model, drives the two K-mirrors in opposite directions through a gear ratio of 89:1

In the manual mode, image rotation is controlled by a front panel potentiometer using a follow up pot connected to the K-mirrors.

1.4.4 Anamorphic Lenses

The two remaining first order distortions are corrected by the anamorphic lenses. The anamorphic distortion can be specified in two ways: (1) in polar coordinates as the magnitude and angle of the anamorphic stretch; (2) in cartesian coordinates as the magnitudes of the differential scale and skew components. The latter can be obtained directly from the distortion analyzer output:

differential scale error Δb = X scale error - Y scale error.

skew error Δc = X skew error + Y skew error.

The two anamorphic lenses do not operate independently in correcting their two distortion components. The required position (or motion) of each anamorph depends on four factors:

(1) Its own orientation

(2) The orientation of the second anamorph

(3) The differential scale error

(4) The skew error

Thus it is necessary to solve two simultaneous equations in order to determine in which direction each anamorph should be rotated to eliminate a given distortion. If an anamorph is rotated in the wrong direction, then the feedback in the correlation loop becomes positive, resulting in oscillation or driving the anamorphs to their extreme position.

The equations to be solved are

$$\dot{\alpha} = \frac{\Delta b \cos 2\beta + \Delta c \sin 2\beta}{1.5 \sin 2(\alpha - \beta)}$$

$$\dot{\beta} = \frac{\Delta b \cos 2\alpha + \Delta c \sin 2\beta}{1.5 \sin 2(\alpha - \beta)}$$

where Δb = differential scale error (x scale - y scale)

Δc = skew error (x skew + y skew)

$\dot{\alpha}$ = angle of first anamorph

$\dot{\beta}$ = angle of second anamorph

As the denominator goes to zero when $\alpha = \beta$ these equations are difficult to instrument. In EROS, the simplification of using only the sign of the trigonometric functions was used, resulting in the equations:

$$\alpha = \mathrm{SIGN}\,(\alpha - \beta)\left[\Delta b \,\mathrm{coSIGN}\, 2\beta + \Delta c \,\mathrm{SIGN}\, 2\beta\right]$$

$$\beta = \mathrm{SIGN}\,(\alpha - \beta)\left[\Delta b \,\mathrm{coSIGN}\, 2\alpha + \Delta c \,\mathrm{SIGN}\, 2\alpha\right]$$

where SIGN 2α is defined as $\frac{\sin 2\alpha}{|\sin 2\alpha|}$

coSIGN 2α is defined as $\frac{\cos 2\alpha}{|\cos 2\alpha|}$

The analog computer used to solve these equations uses sine/cosine potentiometers coupled to the anamorphs to derive the trigonometrical functions, the outputs of the potentiometers being amplified and hard limited to preserve only the polarity of the signal. These signals operate relays which switch when the angles change sign.

The effectiveness of the anamorphic correction varies a great deal with different types of material. The gain required in the anamorph loops varies with the information content of the material viewed. Thus, a gain setting that is satisfactory in one area may cause oscillation in another; if the gain is reduced to avoid oscillation, then there may be insufficient correction in the first area. In practice, a compromise gain setting can be made that will operate with most input material.

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

2. Performance of EROS Feasibility Model

2.1 Optical System

2.1.1 Magnification

The magnification of the optical system is variable over a range of 4:1. Using 10x eyepieces, the effective magnification is 6x to 24x.

2.1.2 Field of View

Field of view with the 10x eyepieces varies from 32mm at 6x to 8mm at 24x with the anamorphs set in the neutral position. When the anamorphs are set to give approximately 2:1 anamorphic ratio, the field of view at 6x magnification is approximately 2.2 x 4.4mm. When the anamorphs are set to give 4:1 anamorphic ratio, the field of view is 1.6 x 4.4mm, (Limited by the diameter of the first field lens).

2.1.3 Exit Pupil

The exit pupil is normally 3mm dia. with a relief of 18mm at minimum magnification and 2.5mm dia. with the relief of 18mm at maximum magnification. At 4:1 anamorphic ratio, the exit pupil is elliptical and measures 4 x 2mm.

2.1.4 Illumination

The illumination level in the film aperture is variable up to about 240 foot candles (open gate). This gives an illumination level of the image in the eyepiece of 1.2 ft-c at minimum magnification and .36 ft-c at maximum magnification. Comfortable viewing with a 10x eyepiece in ambient room light requires about 0.5 ft. candle illumination in the final image.

2.1.5 Resolution

The limiting resolution as measured by observation of a USAF high contrast resolution target at maximum magnification using the 10x eyepieces is 144 lines/mm.

2.2 Scanning System

2.2.1 Cathode Ray Tube

The Scanning CRT was operated at 20kv, with a cathode current of 50μA. The raster size was 0.8 x 0.8 inch.

2.2.2 Video

Video and noise signal levels at the output of the video amplifier were as follows:

	Left Side	Right Side
Noise Voltage (Average)	0.1v	0.2v
Peak Signal Level (Clear Aperture)	1.2v	2.0v
(Typical Photo)	0.3 - 0.5v	0.3 - 0.5v

2.3 Correlation System

Using two correlators covering the Video frequency band of 21.5 - 100 kH_Z, performance of the correlation system was measured with a stereo pair of high resolution panoramic inputs on black and white film. The photographs were first automatically registered in the normal manner and then all the servos were disconnected. The open loop transfer characteristics were then measured one at a time by moving the appropriate optical component from its set position and recording the error voltage at the servo amplifier input. Between each measurement, the system was re-registered automatically.

2.3.1 X and Y Parallax

Minimum magnification - Field of view 32mm.

Error Voltage - ± 1.0 volt for ± 1.5mm parallax

Error Constant - 0.7 volts per mm or 0.225 volts per cent displacement

Pull in Range - Approximately ± 2.5mm

Noise Level - Approximately .05 volt rms.

2.3.2 Zoom Lenses

Magnification approximately 10x.

Error Voltage - ± 5.0 volts for ± 5 per cent magnification change.

Error Constant - 1.0 volts per cent

Pull in Range - Approximately ± 15 per cent

Noise Level - Approximately 0.1 volt rms.

2.3.3 K-Mirrors

Error Voltage - ± 2.5 volts for ± 1/4 degree image rotation.

Error Constant - ± 10 volts per degree image rotation

Noise Level - Approximately 0.1 volt rms.

Note: K-mirror rotation angle is 1/2 image rotation.

2.3.4 Anamorphic Lenses

Two error signals are corrected by the anamorphic lenses, differential scale Δb, and skew, Δc. The four anamorphic lenses are cross coupled in pairs on left and right viewing channels, resulting in only two anamorph control signals.

A change in the orientation of either pair of anamorphs produces both Δb and Δc errors.

The error voltages obtained when the anamorphs are displaced depend greatly on the quality and geometry of the imagery. The following results were obtained with convergent panoramic material of low contrast but with good imagery. The angular separation of the anamorphs was approximately 5° and the cylinder axes were aligned at about -10° to the horizontal axis, i.e., the distortion being corrected was mainly skew.

Anamorph	Angle	Δb	Δc	[illegible]	[illegible]
	Degrees	Volts	Volts	Volts	Volts
α	-2.4	-·20	+·70	-·90	-·65
	0	-·15	-·05	0	-·10
	+2·4	+·20	-·75	+1·15	+·80
β	-2·4			+1·0	+·65
	0			0	0
	+2·4			-1·0	-·75

Noise level (average value measured with DC Meter) 0.1v peak to peak.

From these figures, the correlation error constant for α and β can be estimated at about 0.4 volts per degree of anamorphic lens rotation. This sensitivity was much higher than required; in practice the loop gain was reduced to about 1/5 in order to obtain stable operation.

2.4 Viewing Tests

To determine the overall correlation and scanning capabilities of the EROS viewer, tests were conducted with a variety of input materials.

The types of imagery used for these tests included

1. 9½ x 9½ inch wide angle convergent frame.
2. 70mm high altitude oblique panoramic (black and white)
3. 70mm high altitude oblique panoramic (color)
4. High altitude vertical panoramic (KA 58)
5. Low altitude vertical panoramic (KA 56)
6. Low altitude oblique frame (KA 51A)
7. High altitude oblique frame

STAT

2.4.1 9½ x 9½ wide angle convergent frame photography.

The convergence angle on this material is $\pm 30^\circ$, and the scale difference between corresponding images at the edges of the left and right frames is about 2·5:1. It is therefore a very difficult test of image correlation and was the primary test material used in the development of the equipment.

The EROS viewer will correlate and track this material from edge to edge, providing a good stereo model. Because of the equal convergence angles, a near vertical apparent viewpoint is obtained over most of the frame. Some difficulty is experienced in correlating areas of almost featureless desert and scrub due to the lack of significant imagery. Mountainous areas also are difficult because the large convergence angle (60° between viewpoints) presents totally different image detail in the left and right frames. Because of the rapidly changing distortion (the anamorphic lenses rotate about 90° from edge to edge) the imagery must be scanned quite slowly. This is due mainly to the narrow bandwidth of the servo system, necessitated by the low signal-to-noise ratio of the error signals delivered by the correlator and analyzer. With the improved designs being developed, the scanning rate of future equipment should be considerably increased.

While this imagery is of low resolution (20 - 30 lines/mm) and cannot do justice to the resolution capability of the EROS optical system, it does demonstrate the ability of the equipment to correct automatically considerable geometrical distortion.

2.4.2 High Altitude Oblique Panoramic (black & white)

This material was obtained with a 13" lens at a tilt angle of ±7½ degrees. The imagery consisted of a large city and dock area, partly covered by thin cloud. Good correlation was obtained in all areas except where more than about 50% of the frame was covered by water, and the strip could be scanned quite easily, even into the partially obscured area.

2.4.3 High altitude oblique panoramic (color)

This material was obtained with the same taking parameters as above.

The imagery contained good detail consisting of a city and some wooded hills. Good correlation was obtained and the film could be scanned quite rapidly. Because the optical duplexing system removes blue light from the viewed image, the image had a yellow tint but was very pleasing to look at.

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

2.4.4 High Altitude Vertical Panoramic

This material was obtained from the KA 58 camera which is of 18 inch focal length with a scan of 140°. This material correlated and scanned easily. Alternate panoramic strips, covering the same horizon, were used as stereo pairs, and good results were obtained to within 2 inches of the horizon. At this point the image contrast on film is very low, and the limitation appears to be due to lack of image contrast rather than any lack of distortion correction capability.

2.4.5 Low Altitude Panoramic

This material came from the KA 56 camera of 3 inch focal length with a scan of 180°. Altitude was 2900 feet. Good results were obtained with this material, but the geometrical distortion changes very rapidly in this format, and it was necessary to scan the material fairly slowly. Correlation could be obtained in most areas, but the best scanning was obtained at middle distances (around 45° oblique). It is believed that this is due largely to the imagery rather than the geometry of the format. Near nadir the scale is large and there is little detail on which to correlate (a field of corn covers the whole viewed area, for example, even at lowest magnification.) Near the horizon the image contrast is low.

2.4.6 Low Altitude Oblique Frame (Side looking)

This material was obtained with the KA 51A camera of 6 inch focal length. Results with this material were surprisingly good. The photographs contain high order distortions that cannot be corrected by EROS, but nevertheless an interesting stereo model was obtained.

Major objects such as houses were transformed to their correct average position, but were individually somewhat skewed. This resulted in a stereo model in which nearby vertical objects leaned over. Distant objects appeared normal. The entire photograph could be scanned quite rapidly and stereo accommodation was obtained in all areas.

2.4.7 High Altitude Oblique Frame

This material was obtained with a 36 inch F. L. lens at various angles of obliquity. Chips from both vertical and oblique frames correlated and scanned easily.

STAT

Approved For Release 2004/07/29 : CIA-RDP78B04770A000200010039-8

[redacted]

2.4.9 General Observations

The above tests have shown that the EROS viewer will operate satisfactorily with a wide variety of input materials. Performance was better with some types of photography (notably panoramic) than with others, but in no case was there failure to obtain correlation due to image geometry. With non-photographic inputs [redacted] considerable difficulty was experienced due to the presence of higher order distortions. The anamorphic stretch capability of 4:1 in each channel was more than sufficient to cope with any distortion encountered. In fact a ratio of 2:1 in each channel would probably be adequate. It would be desirable to increase the zoom range to 10:1, to provide more manual zoom range after accommodation of the difference between the scales of the two inputs. The range should be extended at both ends so that fields of view both greater and smaller than at present can be accommodated. This would enable the image content of any area to be adjusted for optimum correlation over a wider range of photographic scale factors. This is especially desirable for low altitude panoramic where the scale changes considerably from nadir to horizon.

As with the ARES viewer, there are a few areas of imagery in which correlation is difficult to obtain. The main causes of poor correlation and their solutions appear to be as follows:

(a) Lack of image detail within correlator passband.

(b) Low contrast imagery.

(c) Different appearance of imagery in left and right channels due to viewpoint, specular reflections, shadows, etc.

(d) Large difference in image detail in X and Y directions.

Lack of image detail within correlator passband.

This can be remedied by increasing the zoom range, increasing the correlator bandwidth, or both. The use of a tunable correlator which selects the frequency band containing most information would be an obvious improvement here. However, it must be borne in mind that the low frequency end of the video spectrum is of greatest importance in establishing initial lock-on.

Low contrast imagery.

The imagery may be of low contrast at any density level. Hence it is necessary to have a video sampling system that will cope with large variations in light level and contrast. This can be achieved by an automatic gain control amplifier that maintains a constant amplitude AC output and suppresses the DC component.

Different appearance of imagery.

When the imagery in left and right channels is appreciably different, the output of the correlator degenerates into noise, which tends to drive the distortion correction components in random directions. The only solution therefore is to monitor the correlator output, and to inhibit operation of the automatic controls when the signal to noise ratio drops below a predetermined figure. This will hold the distortion corrections at their previous value through areas of poor or different imagery. Automatic operation can be resumed without interruption providing that the distortions are still within the lock in range of the system when good correlation is re-established.

Large difference in image detail in X and Y directions

The amplitude of the error signals delivered by the distortion analyzer depend not only on the actual geometric image distortion but also upon the amount of image detail present. One-dimensional image structure is frequently present in aerial photography, e.g. highways, railroads, canals, etc., which produce much higher error signals in one direction than another, depending on their orientation. This creates a special problem with the present correlator and analyzer because two linear distortion errors must be combined to determine each of the two-dimensional optical corrections. For example, the optical rotation error is found by taking the difference between the X skew and the Y skew errors. If there is appreciable diffrence between image detail in X and Y then the X skew and Y skew error voltages may be different even if the geometric distortion is the same in each direction. The result is that in addition to the wanted skew distortion error, a spurious rotation error is indicated.

An unbalance in image detail can similarly produce spurious indications of magnification or anamorphic error. In attempting to correct such non-existent errors, the system may drive out of lock.

The solution to this problem lies in using a distortion analyzer which is better matched to the optical distortion correction parameters. This involves using the correlator output only at those instants in which the scanning spot is moving in a direction in which the optical component can correct image displacement. For example only radial parallax should be used in determining the magnification error, and only rotational parallax should be used in determining the rotation error. A new distortion analyzer based on these ideas is now being developed and will be used on future equipment. A considerable increase in the reliability of correlation should result from this development.

3. REQUIREMENTS FOR FUTURE EQUIPMENT

Development of the EROS breadboard feasibility model has indicated many problems that must be solved in future equipment. These will be briefly described under the headings of the four main subsystems.

3.1 Optical System

3.1.1 The moving elements of the zoom lenses were supplied with considerable clearances (probably to ensure that they never seized up under any circumstances) with the result that random image shifts occur when the lenses are zoomed. These shifts occur so rapidly that the X-Y parallax cannot correct them; they are most noticeable at maximum magnification.

3.1.2 Optical alignment of the system proved extremely difficult, especially the K-mirror. The main problem was adjustment of the three mirrors to obtain rotation of the image about a fixed point. In addition to the K-mirror components there are three fixed mirrors in this part of the optical system each with three adjusting screws which makes a total of 18 adjustments on each side, all affecting image rotation.

3.1.3 It is not sufficient to adjust the spacing of the anamorphic lens elements to perfect collimation (zero power) as they invariably possess small power in the direction of the cylinder axis, due to manufacturing errors. To avoid astigmatism in the final image it is necessary to adjust the lens spacing so that the power in the two directions is equal. This is best done on an optical bench using a collimator and decollimator lens on each side of the anamorph and adjusting the anamorph for minimum astigmatism.

3.1.4 Another problem encountered with the anamorphs was that a significant shift of the image center occurs with anamorph rotation. This is probably due to misalignment of the lens axis with the rest of the optical system. Provision should be made in future for precise adjustment of the anamorph axis.

3.1.5 Due to the presence of two field lenses, some field curvature is apparent in the viewed image. This can be removed by a properly designed negative element in the eyepiece itself.

3.1.6 The viewed image in EROS is inverted due to the use of an even number of image reflections while viewing the input material from below.

3.2 Scanning System

3.2.1 The P16 phosphor peaks at around 4,000Å, a wavelength at which the flint glass elements of the optical system have considerable absorption. This results in a large light loss and necessitates a slow scan and narrow video bandwidth in order to achieve a reasonable signal to noise ratio.

3.2.2 Due to light leakage into the photomultiplier, the brightness of the viewing light source is severely restricted. Even with the use of efficient color filters on the light source and photomultiplier, this is still a problem. The cause is not direct leakage in the lamphouse/photomultiplier assembly (which has been virtually eliminated) but seems mainly due to scattering of the light from the film and other glass surfaces, many of which are plane, back into the photomultiplier.

3.2.3 Because of the yellow color of the viewing light, the viewing of color film is impaired.

These problems can all be solved by the use of a scanning system employing an image dissector or a pair of vidicons.

3.3 Correlation System

3.3.1 Correlation Noise

The major limitation to tracking speed in EROS is the bandwidth of the correlation loop. As the automatic registration system is in effect six phase locked loops in parallel it is necessary for the X- and Y- parallax at least to track the error signals rapidly enough to remain on the linear part of the loop transfer function. Preferably, all of the loops should have this capability. Thus, the bandwidth of the correlation loop is a vital parameter in system performance, and we would like to have this bandwidth as large as possible. The main factor determining the bandwidth of the correlation loop is the signal-to-noise ratio of the error signals at the output of the distortion analyzer.

This is dependent on many factors such as the method of distortion analysis, the CRT or vidicon frame rate and the video signal-to-noise ratio.

In EROS considerable noise is present at the distortion analyzer output and the bandwidth has to be limited to about five cycles per second to provide a useable signal-to-noise ratio. It is most important in future equipment to reduce the correlation noise. While a higher video signal-to-noise ratio would be an advantage, it is believed that a considerable amount of the noise is generated in the distortion analyzer itself. One reason for this may be the fact that the basic scanning motion in the Lissajous pattern is at 45°, while the distortion components are resolved in the X and Y directions. To find X- parallax, the

45° scans are combined so that the X components add and the Y components subtract. However, this results in the noise from both X and Y components being added so that the overall signal-to-noise ratio is halved. A further source of noise may be due to uncompensated second-and higher-order distortion.

A further improvement would result from the use of a higher frame rate (there being a noticeable noise component at the frame frequency), enabling effective filtering to be done without reducing the correlator bandwidth to a low value.

3.4 Servo System

3.4.1 The servo amplifiers used in EROS were of the silicon controlled rectifier type using a 60 c/s power supply. These amplifiers do not give a smooth output due to the presence of 60 c/s pulses, and they are tricky to operate because the control pulses cause interference to other units. Linear DC amplifiers are recommended for future designs.

3.4.2 Printed motors were used as power transducers. While these are potentially capable of direct drive operation at very low speeds, this proved unsatisfactory due to the rough output of the SCR amplifiers. Because of their very low resistance, special amplifiers are required for printed motors. Because of this it may be preferable to use Inland Torque Motors which can be obtained in higher resistances.

In any case, direct drive motors with tachometer feedback seem to offer the best method of driving the optical components as this system ensures small dead band, linearity, and absence of friction and backlash.

3.4.3 An effective method of eliminating the drive from a zoom lens when it reaches the limit of its travel and transferring it to the other zoom lens should be provided. In EROS, slip clutches are provided which safeguard the lenses, but this results in the reduction of loop gain by a factor of 2 when either lens is drive to the limit of its travel.

3.4.4 The loop gain of the X and Y parallax loops varies with the magnification of the optical system. It is necessary, therefore, to vary the X-Y parallax loop gain with zoom lens setting. This could be achieved by ganging two gain pots (connected in the X and Y parallax servo loops) with the main zoom control.

4. Conclusions

The feasibility of combining an optical viewing and distortion correction system with an electronic image correlation system has been established.

Using off-the-shelf components, the resolution of the feasibility model was 144 lines/mm at 24x magnification, and it proved capable of correcting X and Y image parallaxes and all first order distortions to a degree adequate for comfortable stereo viewing. The first order distortion correction capability of the instrument was more than adequate to deal with any material tested.

The rate at which film could be scanned varied considerably with the type of material. High altitude panoramic material, in which the distortion parameters change relatively slowly, could be scanned at about 1 inch per second at 6x magnification without loss of correlation. The scanning rate with low altitude and oblique material was somewhat lower due to the rapidly changing distortion and the limited bandwidth of the correlation system.

The major limitations on performance as far as reliability of lock and scanning speed are concerned lie entirely in image sampling, correlation and distortion analysis i.e., the electronic system. Potential improvements in this area have already been discussed in some detail. The problem of driving the anamorphic lenses finally yielded to a simple analog computer.

No basic problems are foreseen in the optical system, and no difficulty was experienced in driving the large optical components at the required rates and to the necessary precision.

Development of this feasibility model has provided valuable information on the future operational possibilities of this type of equipment. It has provided a solid basis for future designs, and has indicated the areas of technology where most development effort should be concentrated.

STAT

Next 1 Page(s) In Document Exempt